Assessing the Robustness of the Salmon Stock Assessment Process via a Life History Simulator

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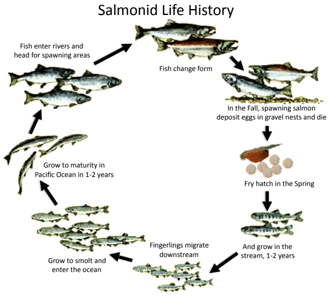
Introduction

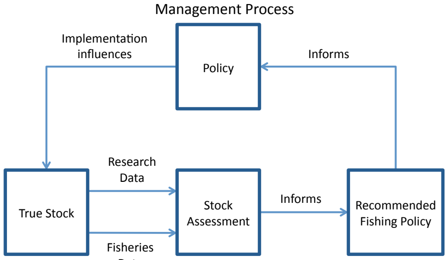
• Government agencies, including the National Marine Fisheries Service (NMFS), strive to conserve, protect, and manage living marine resources. In particular, managers are interested in obtaining accurate estimates of abundance for the species of interest in order to establish policies such as catch limits (i.e. the total allowable biomass removal for that fishing season).
• Salmonids are of particular interest to managers due to their complex life history, the recent decline in their abundance, and their importance for both recreational and commercial fisheries.

Salmonid Life History

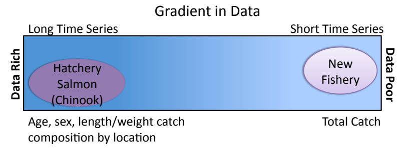


• The fishery management process typically involves the following steps:
 −Obtain all available data (fisheries data and fisheries independent data)
 −Use appropriate data as inputs to a (typically) complex statistical analysis, resulting in an estimate of abundance (this is the stock assessment)
 −Use the estimate of abundance to recommend fishing regulations to policy makers
 −Implement the fishing regulation next season and repeat the process
• Fisheries data (landings) may include:
 −Fishery type (commercial, recreational)
 −Total catch (biomass)
 −Geographic area of catch
 −Month and year of catch
 −Fishing effort
 −Age, sex, length, and/or weight composition of catch
• Fisheries independent data (coded wire tags, hatcheries, egg/larval survey) may describe:
 −Movement and dispersal
 −Natural mortality estimates
 −Growth rates

Management Process



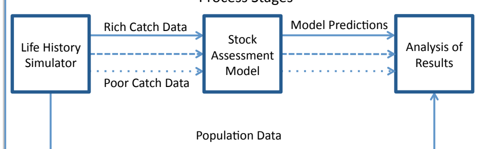
• Within a stock assessment assumptions about life history parameters, structure, and population dynamics of the stock are necessarily made; i.e. the natural mortality rate of a stock cannot be directly observed, thus a rate is estimated from the available data.
• Additionally, the amount and type of data available for a stock varies drastically; many stocks are not well documented due to funding and time constraints. This leads to another issue: data poor stocks. Performing a stock assessment on a data poor stock requires further estimations and assumptions.
• Our project proposes to 1) test the robustness of stock assessment tools to the assumptions made regarding life history parameters, structure, and population dynamics, and 2) test the effectiveness of stock assessments in data poor scenarios.



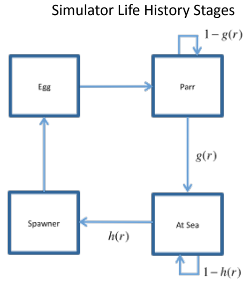
Simulator

• In order to test the robustness of a stock assessment, first we must simulate a stock, thus creating a completely parameterized population. Next, we apply a stock assessment to the stock, possibly with different life history parameters, structure, and/or population dynamics than those used to create the simulated stock. Finally, we compare the simulated stock to that produced by the assessment.
• This model has the potential for application across many salmon species, however we have chosen to focus on the following two: coho (*Oncorhynchus kisutch*) and chinook (*Oncorhynchus tshawytscha*).

Process Stages



Simulator Life History Stages



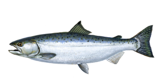
Cohort Reconstruction

• The assessment we performed was that of a cohort reconstruction. The inputs to the cohort reconstruction are age specific escape S(a,t) and catch Y(a,t), over time. The purpose of a cohort reconstruction is to estimate ocean abundance by working backward through time.
• Starting with the most recent data (time t+1) and the oldest age (a+1), the abundance is calculated for the previous time (t) step and age (a), as shown below, where M is the natural mortality rate.

$$\hat{A}(a,t) = \begin{cases} Y(a,t) + e^{M}(S(a,t) + \hat{A}(a+1,t+1)) & \text{for } a = 2,\ldots,7 \\ 0 & \text{for } a \geq 8 \end{cases}$$

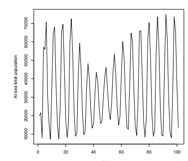
Cohort Reconstruction Steps

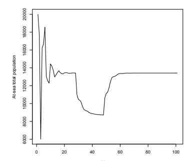
Age → Time ↓	a=2	a=3	a=4	a=5	a=6	a=7	a=8
t=1	Â(2,1)						0
t=2							0
⋮							⋮
					Â(6,T-1)		
t=T						Â(7,T)	0
t=T+1	Â(2,T+1)	Â(3,T+1)	Â(4,T+1)	Â(5,T+1)	Â(6,T+1)	Â(7,T+1)	0

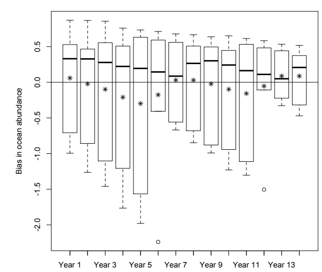


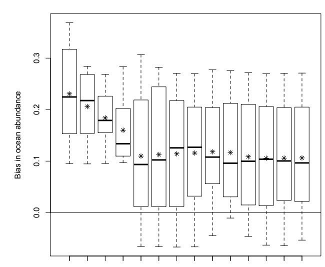
Results

Below is sample output from the simulator. We investigated the importance of the size dependent term in the natural mortality rate. In the top left and middle figures the natural mortality is constant (no size dependent term; referred to as CM from here on), and in the top right and bottom figures there is a size dependent natural mortality term such that larger fish experience less natural mortality (variable mortality; referred to as VM from here on). With all other parameters held constant, the CM population dynamics are oscillatory, while the VM population dynamics are not. Since the cohort reconstruction only considers constant natural mortality, we are interested in the differences in bias ((actual population-estimated)/estimated) between the CM and VM case.









Since the cohort reconstruction only considers one life history stage, at-sea, and the simulator tracks the population dynamics for four life history stages, even if all the parameter values are the same between the simulator and the assessment, we still expect discrepancies in the resulting abundance values, as we observe here for the CM case. Further simulation runs with differing parameters are required to facilitate comparisons between two non-oscillatory populations, with different natural mortality rates.

Future Applications

Using the simulator in conjunction with state dependent life history theory, we will investigate optimal life history trajectories and growth strategies, and predict how these strategies influence population dynamics.

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